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VOLUME II

FINAL REPORT — PROJECT 2

HOT ISOSTATICALLY PRESSED
MANUFACTURE OF HIGH STRENGTH MERL 76
DISK AND SEAL SHAPES

BY

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JULY 1982

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ABS: The performance of a HIP MERL 76 disk installed in an experimental engine and exposed to realistic operating conditions in a 150 hour, 1500 cycle endurance test is examined. Post test analysis, based on visual, fluorescence penetrant and dimensional inspection, indicates that the disk performs satisfactorily.

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16. ABSTRACT This report documents the performance of a HIP MERL 76 disk installed in an experimental engine and exposed to realistic operating conditions in a 150 hour, 1500 cycle endurance test. Post test analysis, based on visual, fluorescent penetrant and dimensional inspection, indicated that the disk performed satisfactorily. The results reported herein cover the work performed under Tasks IV and V of MATE Project 2, and is presented as FEDD category 2 data. Work performed under Tasks I, II and III of this contract is presented in NASA CR-165549.			
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1.0 SUMMARY

The purpose of this program was to demonstrate the feasibility of using MERL 76, an advanced, high strength, direct hot isostatic pressed powder metallurgy superalloy as a full scale component in a high technology, long life commercial gas turbine engine. The specific objectives of Tasks III and IV were to fabricate and demonstrate the performance of a MERL 76 disk in an actual engine test. The results of these tasks are reported in this document.

The HIP disk was installed in a land-based experimental JT9D engine for testing at realistic operating conditions. The disk was successfully tested for 150 hours (1500 cycles). Based on visual, fluorescent penetrant and dimensional inspection, the HIP disk performed satisfactorily in the engine test.

2.0 INTRODUCTION

BACKGROUND

The demand to improve engine operating economics has created a need to develop materials that can be fabricated into disk components that are able to withstand higher turbine inlet temperatures and greater rotor speeds. Since component durability contributes directly to maintenance costs and since this durability derives its capability from the fatigue characteristics of the material, developing new materials having greater strength and creep properties with superior cyclic properties would lower the operating costs of aircraft turbine engines. The material must be compatible with low cost fabrication techniques. The powder metallurgical approach was selected to develop the properties in these advanced disk designs. Direct hot isostatic pressing of the powder to a near sonic shape has been shown to be a particularly effective method of producing low cost disks.

To establish production disk fabrication for advanced aircraft powerplants, such as energy efficient engines, several factors, such as the alloy chemistry which is capable of achieving the required strengths, and the disk processing which will produce HIP net sonic shape must be considered. Through an internally funded program, P&WA identified an alloy capable of achieving properties comparable to GatorizedTM IN-100 in the as-HIP condition. Known as MERL 76, this alloy is of modified IN-100 base, with a nominal composition Ni-12.4 Cr-18.5 Co-3.2 Mo-0.75 Hf-1.65 Nb-5.0 Al-4.3 Ti-0.025 C-0.02 B-0.045 Zr.

To accelerate the development of material technologies, such as MERL 76, to the point where they can be verified through engine testing, a five year cooperative Government/Industry effort, Materials In Advanced Turbine Engines, was initiated under NASA sponsorship. This effort is Project 2 of the specific materials technology programs under MATE.

MERL 76 has demonstrated the potential for improvement in cyclic fatigue life capability with improved resistance to corrosion and at a lower cost because of its HIP processability over IN-100.

Under Project 1, manufacturing methods to produce direct HIP + heat treated Low Carbon Astroloy JT8D first stage turbine disks were established for the following areas:

- o Powder manufacture and storage
- o Disk shape container design and fabrication
- o Powder outgassing and transport from storage to disk shape container
- o HIP consolidation cycle tolerances

Based on the results of Project 1 and the alloy development program at Pratt & Whitney Aircraft, MERL 76 with a modified chemical composition was selected to demonstrate its feasibility as a full scale component in a high technology, long life, commercial gas turbine engine. The specific goals of project 2 were as follows:

- o Increase the JT9D disk rim temperature capability by at least 22°C (40°F) over disks produced from Superwaspaloy.
- o Reduce the weight of JT9D high pressure turbine rotating components by at least 35 pounds by replacement of forged Superwaspaloy components with hot isostatic pressed MERL 76 components.
- o Reduce JT9D disk manufacturing costs by at least 30 percent relative to Superwaspaloy disks.

This volume presents the FEDD category 2 technical effort accomplished in MATE Project 2. Category 2 data includes an engine test program and post test analysis of a direct HIP MERL 76 turbine disk. Category 1 data was reported in Volume I (NASA CR-165549).

PROGRAM SCOPE

Project 2 comprised the following tasks:

Task I identified the manufacturing procedures necessary to produce MERL 76 turbine disks and tangential on-board injection rotor seals, and established design allowable data using these components. All turbine disks and rotor seals were manufactured by the Udimet Powder Division of Special Metals Corporation. These disks used a JT10D sonic shape and a JT9D sonic shape. An initial group of consolidations was used to establish and refine hot isostatic pressing conditions and a heat treatment to achieve target properties. The results of this initial group were used to refine the manufacturing process which led to the generation of a process control plan and acceptance criteria to HIP MERL 76 components. The next three disks were used to establish design allowable properties data.

Task II HIP consolidated and finish machined one disk for spin burst rig testing. The turbine disk was tested at five spin speeds up to 140.5 percent overspeed at which point the rig failed before the disk. Task III HIP consolidated and finish machined one disk for a ground based JT9D experimental engine test. In Task IV, one turbine disk was subjected to full scale JT9D experimental engine test. Task V provided the post-test analysis of the entire program. The engine test disk was hot isostatically pressed to the target configuration shown in Figure 1 and was subsequently heat treated to achieve the mechanical properties shown in Table I. After heat treatment, the disk was machined to the configuration shown in Figure 2.

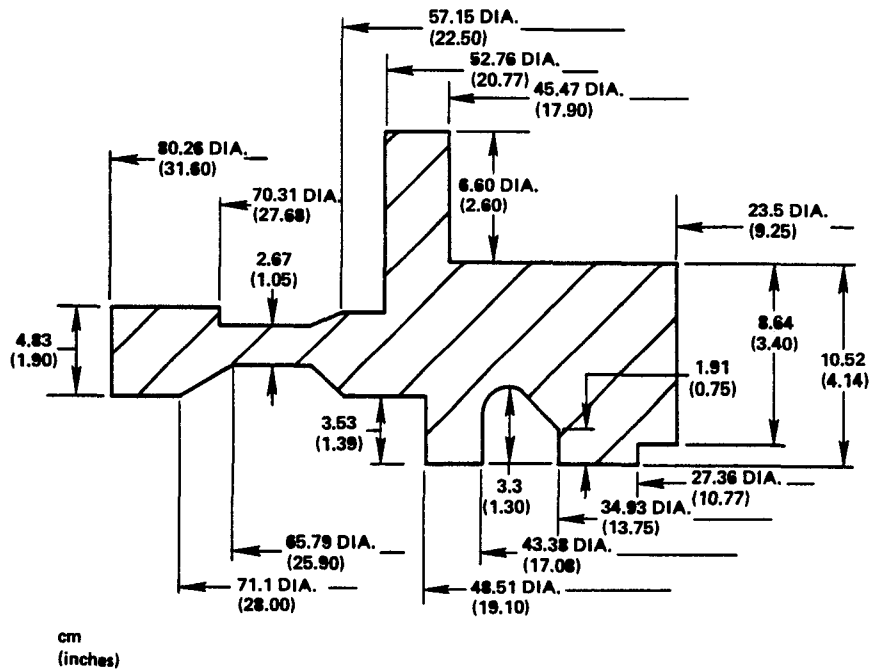


Figure 1 Target Shape for JT9D Disk

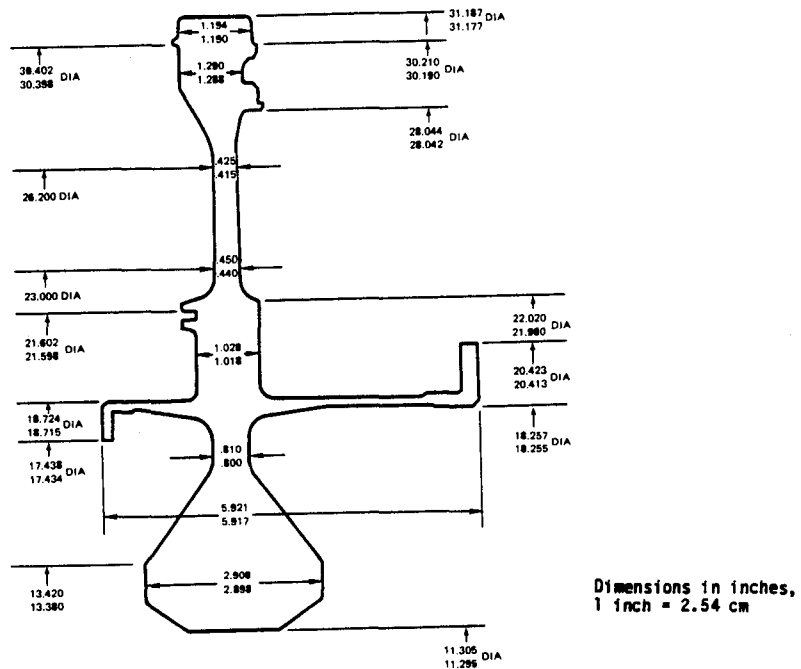


Figure 2 Principal Dimensions of JT9D First Turbine Disk P/N 812901

TABLE I

MECHANICAL PROPERTY REQUIREMENTS
FOR HIP MERL 76 POWDER DISKS

TENSILE GOALS

	0.2% Yield Strength <u>MPa (Ksi)</u>	Ultimate Tensile Strength <u>MPa (Ksi)</u>	Elongation <u>(%)</u>	Reduction in Area <u>(%)</u>
21°C (70°F) Tensile	1034 (150)	1482 (215)	15.0	15.0
704°C (1300°F) Tensile	1014 (147)	1172 (170)	12.0	12.0

STRESS-RUPTURE GOALS

	<u>Life</u>	<u>Elongation (%)</u>
732°C (1350°F)/ 638 MPa (92.5 Ksi)	23 hrs.	5

CREEP GOALS

	<u>Time to 0.2% Elongation</u>
704°C (1300°F)/ 552 MPa (80 Ksi)	100 hrs.

3.0 DEMONSTRATION ENGINE TEST PROGRAM

A direct HIP MERL 76 first stage turbine disk 160-3 (P/N 812901) was engine tested in a land-based JT9D engine designated as X-619-22. The details of the manufacturing procedures for disk 160-3 (Figure 3) have been reported in Volume I, CR-165549. The HIP disk was tested in a 150 hour, 1500 cycle test program comprising idle, take-off, and intermediate power settings as illustrated schematically in Figure 4. A summary of the accumulated exposure times for the test is given in Table II and some of the test conditions to which the disk was exposed are included in Table III.

This engine test program was typical of engine tests conducted for Federal Aviation Administration certification of new engine models and/or new engine components.

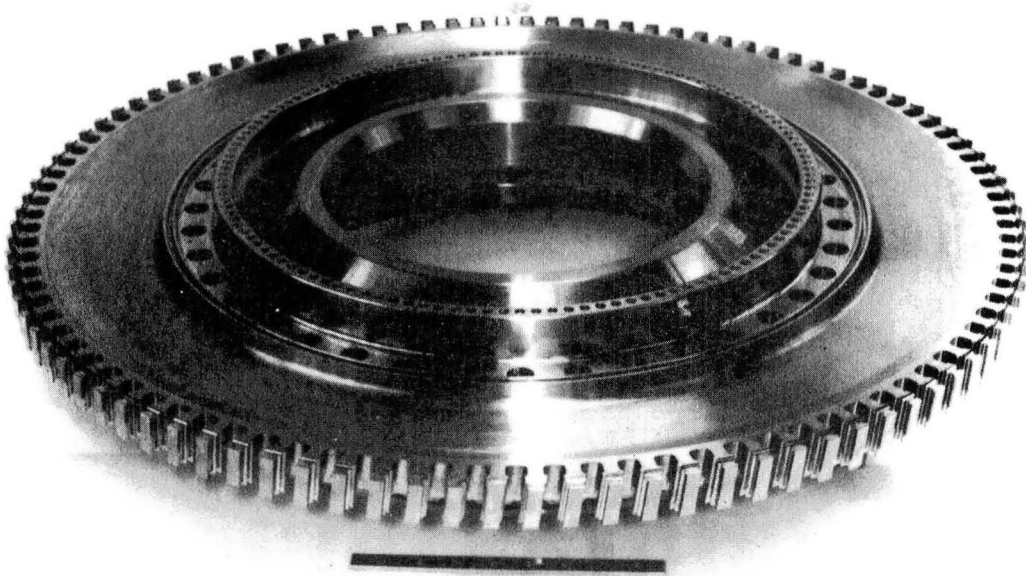


Figure 3 Front View of Finish Machined MERL 76 JT9D First Stage Turbine Disk

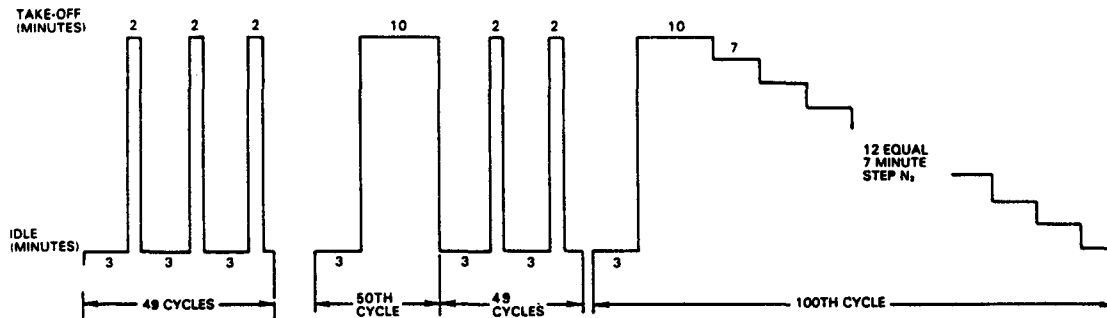


Figure 4 Schematic of JT9D Experimental Test Engine Cycle, Showing 100 Cycles of 150 Hour/ 1500 Cycle Endurance Test

TABLE II

EXPOSURE TIME FOR MERL 76
FIRST STAGE TURBINE DISK IN ENGINE X-619

<u>Power Setting</u>	<u>Total Time-Hours</u>
Take-Off	36
Step-Down From High to Idle	14
Idle	100
Total	150 hours

TABLE III
TYPICAL DISK OPERATING PARAMETERS

<u>Test Parameters</u>	<u>Values</u>
Average Disk Temperature	1102°F (595°C)
Maximum Disk Temperature	1149°F (620°C)
Average Tangential Stress	79.9 ksi (551 MPa)
Exhaust Gas Temperature	1265°F (685°C)
Thrust	53,000 lbs. (24,105 kg)

4.0 POST ENGINE TEST ANALYSIS

After the 150 hour, 1500 cycle engine test, the disk was removed for visual, fluorescent penetrant and dimensional inspection. Visual and fluorescent penetrant inspection of the disk showed no defects (i.e., cracks or corrosion). Selected diametral dimensions of the disk were measured before and after the engine test and are given in Table IV.

TABLE IV
DIAMETRAL DIMENSIONS BEFORE AND AFTER ENGINE TEST

<u>Location</u> ¹	<u>Diameter, Pre-Test</u>	<u>Diameter, Post-Test</u>
Snap A	47.549 cm (18.720 in.)	47.554 cm (18.722 in.)
Snap B	46.368 cm (18.255 in.)	46.370 cm (18.256 in.)
Dia. A	54.869 cm (21.602 in.)	54.869 cm (21.602 in.)
Dia. B	28.697 cm (11.298 in.)	28.697 cm (11.298 in.)
Dia. C	28.697 cm (11.298 in.)	28.697 cm (11.298 in.)
Dia. D	71.234 cm (28.045 in.)	71.234 cm (28.045 in.)

(1)As shown in Figure 5

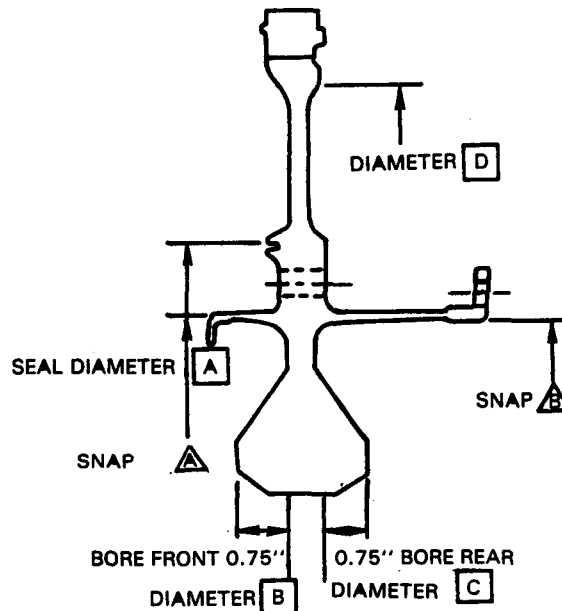


Figure 5 Locations for Measurement of Engine Tested Disk 160-3

5.0 CONCLUSIONS

This demonstration test was conducted to expose a HIP MERL 76 JT9D first stage turbine disk to an experimental land-based engine test using realistic operating test conditions. Upon completion of the test, including post-test inspection, it was concluded that the objectives of the test were successfully completed.

